

JOURNAL
OF THE
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OF
CIVIL ENGINEERS



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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, SEPTEMBER 19, 1917,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Frank A. Barbour, supervising engineer at Camp Devens, Ayer, Mass., will give an informal general description of the work at that camp, illustrating his talk with lantern slides. As many of the chiefs of the engineering divisions as can arrange to be present will describe in greater detail the work done in their various branches.

S. E. TINKHAM, *Secretary.*

MEMBERS ENGAGED IN WAR WORK.

Will members of the Society who are in any branch of the U. S. military or naval service, or who are doing war work in any department of the government, kindly send to the Secretary their correct titles and addresses? It seems advisable to maintain at Society headquarters a list of members so engaged, and the Secretary would appreciate being kept informed along these lines.

PAPERS IN THIS NUMBER.

"History of the Boston Dry Dock." James W. Rollins.

"The Discharge Integrator." Charles H. Pierce.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETING.

BOSTON, June 6, 1917. — A regular meeting of the Sanitary Section, Boston Society of Civil Engineers, was held this evening in the Society Library, Tremont Temple.

The meeting was called to order at 7.50 o'clock by the Chairman, Frank A. Marston. The records of the annual meeting were approved as printed in the April JOURNAL.

The Chairman stated that the Clerk of the Section, Arthur D. Weston, would be unable to serve for several months because of his appointment to the Officers' Reserve Training Camp. John P. Wentworth was elected Clerk pro tem. during Mr. Weston's absence.

The speaker of the evening was Prof. Robert Spurr Weston, who gave a very interesting talk on the "Biological Self-Purification of Coweaset River, Brockton, Mass." The talk was illustrated with lantern slides, prints and microscopical slides.

It was voted to extend the thanks of the Section to Professor Weston, for his interesting address.

There were twenty-two present. Meeting adjourned at 10.15 o'clock.

JOHN P. WENTWORTH, *Clerk pro-tem.*

NEWTON, MASS., June 13, 1917. — A regular meeting of the Society was held at Norumbega Park, Newton, Mass., on Wednesday, June 13, 1917, and was called to order at 2.45 P.M. by the President. This meeting was held after a ball game and a dinner, in which the New England Water Works Association took part. There were present 31 members of the Society and

119 guests, including ladies and members of the N. E. W. W. A., a total of 150. In the absence of the Secretary, Mr. Charles W. Sherman was designated to act as Secretary.

The records of the regular meeting of May 16 were read and approved.

The acting Secretary reported for the Board of Government that it had elected the following applicants for membership in the various grades:

Members — Messrs. Anthony S. Coombs, William James Long, Walter Thomas Palmer and Louis J. St. Amand.

Juniors — Messrs. Laurence Joslyn Phillips and Hyman Benjamin Ullian.

Associate — Mr. Arthur Frederick Probst.

The acting Secretary also reported for the Board of Government that the letter ballot for endorsement of the formation of an engineer regiment in the Massachusetts National Guard had been canvassed, as directed by the meeting of May 16; that 296 members had voted in the affirmative and 8 in the negative, and that the resolution was adopted.

The question on the motion "that a sum not exceeding \$500 be appropriated from the income of the Permanent Fund for the improvement and furnishing of the Society rooms," which was voted at the May meeting, was put a second time, as required by the By-Laws, and was passed, 23 members voting in the affirmative and none in the negative.

The President announced the death of Franklin B. Locke, a member of the Society, which occurred May 11, 1917. On motion, the President was instructed to appoint a committee to prepare a memoir of Mr. Locke. As such committee the President has appointed Messrs. Richard A. Hale and George F. Swain.

Mr. William S. Johnson moved the adoption of the following resolutions:

WAR PROHIBITION.

Whereas, on account of a state of war, it is necessary that this country conserve its sources of food supply to the utmost; and

Whereas, immense quantities of grain, molasses and other food products are now used in the manufacture of distilled and fermented liquors;

Be it resolved, that the members of the Boston Society of Civil Engineers present at this meeting favor such Congressional action as will result in the prohibition of the manufacture and sale of distilled and malt liquors in the United States during the continuance of the war; and

Be it resolved, that copies of this resolution be sent to the President of the United States and to the Senators and Representatives who represent the Commonwealth of Massachusetts in Congress.

The motion was seconded by Mr. Sanford E. Thompson, and was carried unanimously. On motion of Mr. Thompson, it was voted that in forwarding copies of this resolution, it should be noted that it was passed by a unanimous vote.

Adjourned at 2.55 P.M.

CHARLES W. SHERMAN, *Acting Secretary*.

APPLICATIONS FOR MEMBERSHIP.

[September 4, 1917.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

GOLDMAN, SAM, Detroit, Mich. (Age 21, b. Volkinsk, Russia.) Student for three years at Y. M. C. A. Coöperative Engrg. School. In 1915, inspector with Boston Transit Comm. on Dorchester Tunnel; in 1916, draftsman with Massachusetts Highway Comm.; from 1916 to 1917, draftsman with New England Structural Co.; from 1917 to date, in private practice as civil engineer, specializing in city surveying. Refers to C. S. Ell, A. E. Kleinert, Jr., A. M. Lovis, P. C. Nash, A. F. Probst and Max Silverman.

KENDALL, THEODORE REED, Jersey City, N. J. (Age 27, b. Boston, Mass.) Received degree of S.B. from Harvard College, 1912, and degree of M.C.E. from Harvard Graduate School of Applied Science, 1914. In 1915, employed by Prof. G. C. Whipple; from January, 1916, to March, 1917, employed by Panama Canal as chemist in charge of Agua Clara Filtration Plant, Gatun, Canal Zone; from March, 1917, to date, engineering editor *The American City*, New York, N. Y.; elected an associate, November 17, 1915, and now desires to be transferred to grade of member. Refers to Fred-eric Bonnet, Jr.; H. J. Hughes, L. J. Johnson, F. A. Marston, R. S. Weston and G. C. Whipple.

LAPHAM, SAMUEL, Jr., Akron, Ohio. (Age 25, b. Charleston, S. C.) Graduate of College of Charleston, 1913, degree of A.B., and of Mass. Inst. of Technology, 1916, architectural engineering course, degree of S.B. From June to September, 1914, draftsman with D. C. Barbot, architect, Charleston; from June to November, 1916, with Brigham, Coveney & Bisbee, architects, Boston; from July, 1916, to 1917, architect for Gainor & Burton, contractors, Charleston, on Chicora Place development project; from November, 1916, to February, 1917, with Fay, Spofford & Thorndike, Boston; is now with Carmichael Const. Co., Akron, Ohio. Refers to C. R. Berry, F. H. Fay, R. W. Horne, W. H. Lawrence, C. M. Spofford and S. H. Thorndike.

LEAVITT, ALBERT JOSEPH, Foxboro, Mass. (Age 27, b. Boston, Mass.) Student at Franklin Inst., 1910 to 1913, mechanical and electrical engineering course. From 1905 to 1908, with F. O. Thaxter, electrical contractor; from 1908 to 1909, with T. W. Byrne, electrical contractor; from 1909 to 1910, with E. C. Lewis, electrical contractor; from 1910 to 1911, with East Boston Gas Co. on construction work; from 1911 to 1912, with American Voting Machine Co. on machine design; from 1912 to 1913, with Holtzer-Cabot Co.; from 1913 to 1914, with F. A. Hartshorn, Walpole; from 1914 to 1915, with Phillipsdale Paper Co., Phillipsdale, R. I.; in 1916, with Stone & Webster Engrg. Corp'n; from October, 1916, to date, with White, Weld Co. Refers to W. A. Brown, R. O. Delano, H. W. Hayward and H. S. Kimball.

LIST OF MEMBERS.

ADDITIONS.

COOMBS, ANTHONY S.....	73 Harvard Ave., Allston, Mass.
LONG, WILLIAM J.....	46 Front St., Woonsocket, R. I.
PALMER, WALTER T.....	43 Hobson St., Faneuil, Mass.
PHILLIPS, LAURENCE J.....	70 Devonshire St., Boston, Mass.

CHANGES IN ADDRESS.

ALLARD, THOMAS T.....	912 Liberty Bldg., Philadelphia, Pa.
BOAS, BENJAMIN.....	Care Colt Patent Fire Arms Co., Hartford, Conn.
BOWERS, GEORGE W.,	
Care Constructing Quartermaster,	Chillicothe Cantonment, Chillicothe, Ohio
BROWN, C. LEONARD.....	1339 15th St., N. W., Washington, D. C.
EBERHARD, WALTER C.....	138 Poplar St., Roslindale, Mass.
ELKINS, CLAYTON R., Lieut., Public Works Dept., Navy Yard, Norfolk, Va.	
HAMMOND, N. LEROY.....	82 Walpole St., Norwood, Mass.
HOLWAY, WILLIAM R.....	Office of City Chemist, Alliance, Ohio
HUBBARD, CARL P.....	Sergeant, Co. D, 1st Engrs., U. S. Nat'l Army
MEAD, ROYAL L.....	Box 182, Jackson, Mich.
MOORE, LEWIS E.,	
Capt., 3d Co., Engrs. Training Camp, American Univ., Washington, D. C.	
SNOW, LESLIE W.,	
Lieut., Gun Div., Office Chief of Ordnance, 1330 F St., Washington, D. C.	
STENBERG, THORNTON R.,	Co. 5, 1st N. E. Regiment, Plattsburg, N. Y.
	Home address, 23 Burncoat St., Worcester, Mass.
SUMNER, MERTON R.....	Radnor Mills, Elkton, Md.
WARING, CHARLES T., Captain, Aviation Section, Signal Officers' Reserve Corps, 1015 North Main St., Dayton, Ohio	
WEBB, DEWITT C., Public Works Office, U. S. Navy Yard, Philadelphia, Pa.	
WELLS, CHARLES E.....	32 Prospect St., White Plains, N. Y.
WORCESTER, ROBERT J. H.,	
Eighth Co., 17th Provisional Regiment, Plattsburg Barracks, N. Y.	

DEATH.

MILLER, STANLEY A.....	May 13, 1917
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EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for

furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

402. Age 28. Student for two years at Cornell University, civil engineering course. Experience consists of work on two sewage disposal plants. Desires position as transitman, levelman or rodman.

403. Age 29. Took special course at Harvard. Has had ten years' experience along engineering lines. Desires position as superintendent of construction or as draftsman, designer or detailer on architectural design.

404. Age 27. Graduate of Tufts College, 1912, civil engineering course. Experience includes four and one-half years on railroad work as transitman and assistant to supervisor of track; and one year as sub-foreman on form building and general concrete work; has also had some experience as timekeeper and draftsman. Desires position as transitman or as assistant superintendent or foreman on construction work.

405. Age 28. Student for two years at Case School, Cleveland, Ohio; graduate of Mass. Inst. of Technology, 1912, degree of B.S. Has had about four years' experience as rodman and transitman on general survey work, two months on right-of-way work for transmission line, and two months as inspector on highway work. Desires position as transitman. Minimum salary desired, \$85 per month.

406. Age 36. Graduate of Mechanic Arts High School, Boston; student for one year at Mass. Inst. of Technology and for three years at Franklin Union. Has had nearly fourteen years' experience, including one year as rodman, two years as transitman on railroad location and property surveys, one year on construction work (Charles River Basin), four years in bureau of topography, three years on town work and private surveys, and two years as draftsman and inspector on concrete work. Desires position as draftsman or chief-of-party. Salary desired, \$25 per week.

407. Age 40. Has had about seven years' experience as resident engineer on railroad construction. Desires position as engineer in charge of outside construction or as inspector.

408. Age 62. Has had wide experience along engineering lines, including two years as U. S. Asst. Engr., chiefly on harbor work; eight years on municipal work, and twenty-two years as assistant engineer for prominent railroads. Salary desired, \$100 per month.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

On Military Engineering and Related Subjects.

Individual and Combined Military Sketching. Edwin T. Cole and Edwin R. Stuart.

National Service Handbook. U. S. Committee on Public Information.

Trench Warfare. J. S. Smith.

U. S. Government Reports.

Annual Report of Director of Office of Public Roads and Rural Engineering.

Antimony, Arsenic, Bismuth, Selenium and Tellurium in 1915. Frank L. Hess.

Artificial Gas and By-Products in 1915. C. E. Leshner.

Automobile Registrations, Licenses and Revenues in United States, 1916.

Cleveland Gas Field, Cuyahoga County, Ohio, with Study of Rock Pressure. G. Sherburne Rogers.

Cobalt, Molybdenum, Tin, Titanium, Tungsten, Radium, Uranium and Vanadium in 1915. Frank L. Hess.

Cotton Production in United States, Crop of 1916.

Crossties Purchased and Treated in 1915. Arthur M. McCreight.

Drainage of Irrigated Farms. R. A. Hart.

Gold and Silver in 1915. H. D. McCaskey and J. P. Dunlop.

Nursery Practice on National Forests. C. R. Tillotson.

Oil Resources of Black Shales of Eastern United States. George H. Ashley.

Properties of Calcium Silicates and Calcium Aluminate Occurring in Normal Portland Cement. P. H. Bates and A. A. Klein.

Results of Physical Tests of Road-Building Rock in 1916, including All Compression Tests. Prévost Hubbard.

Seasoning of Wood. Harold S. Betts.

Status and Value of Farm Woodlots in Eastern United States. E. H. Frothingham.

Tests of Western Yellow Pine Car Sills, Joists and Small Clear Pieces. C. W. Zimmerman.

Use of Mean Sea Level as Datum for Elevations. E. Lester Jones.

Utilization of Ash. W. D. Sterrett.

Water-Supply Paper 400-E.

State Reports.

Massachusetts. Annual Report of Public Service Commission for 1916, Vol. I.

Massachusetts. Annual Report of Commission on Waterways and Public Lands for 1916.

Massachusetts. Annual Report of Metropolitan Park Commissioners for 1916.

Massachusetts. Annual Report of Metropolitan Water and Sewerage Board for 1916.

Massachusetts. Annual Report of Gas and Electric Light Commissioners for 1916:

New Jersey. Annual Report of Commissioner of Public Roads for 1916.

New Jersey. Annual Report of Department of Conservation and Development for 1916.

New York. Annual Report of Public Service Commission for First District for 1915, Vols. I and II.

New York. Annual Reports of State Engineer and Surveyor for 1915 and 1916. 4 vols.

Pennsylvania. Annual Reports of Commissioner of Health for 1913 and 1914. 4 vols.

Municipal Reports.

Albany, N. Y. Annual Report of Bureau of Water for 1916.

Bangor, Me. Annual Report of Water Board for 1916.

Boston, Mass. Reports and Communications of Finance Commission, 1917, Vol. XII.

Brockton, Mass. Annual Report of City Engineer for 1916.

Brockton, Mass. Annual Report of Sewerage Commissioners for 1916.

Cambridge, Mass. Annual Report of City Engineer for 1915-16.

Concord, N. H. Annual Report of Water Commissioners for 1916.

Erie, Pa. Annual Report of Commissioners of Water Works for 1916.

Fitchburg, Mass. Semi-Annual Reports of Sewage Disposal Commission for 1916.

Haverhill, Mass. Annual Report of Water Commissioners for 1916.

Leominster, Mass. Annual Report of Water Commissioners for 1916.

Lynn, Mass. Annual Report of Commissioner of Water and Water Works for 1916.

Marlborough, Mass. Annual Report of Water and Sewage Commission for 1916.

New Orleans, La. Semi-Annual Report of Sewerage and Water Board, December, 1916.

New York, N. Y. Annual Report of Department of Water Supply, Gas and Electricity for 1916.

Philadelphia, Pa. Report upon Proposal of Philadelphia Rapid Transit Company for Equipment and Operation of City-Built High-Speed Lines. Gift of H. S. Knowlton.

Pittsfield, Mass. Annual Report of Board of Public Works for 1916.

Plainfield, N. J. Annual Report of City Officers for 1916.

Providence, R. I. Annual Report of City Engineer for 1916.

Revere, Mass. Annual Report of Public Works Department for 1916.

St. Louis, Mo. Annual Report of Water Commissioner for 1916.

St. Paul, Minn. Annual Report of Water Commissioners for 1916.

Salt Lake City, Utah. Annual Reports of Officers for 1916; Appropriation Budget for 1917.

Somerville, Mass. Annual Reports for 1916.

Taunton, Mass. Annual Report of Water Commissioners for 1916.

Waltham, Mass. Annual Reports of City Engineer and Superintendent of Water Works and Sewers for 1916.

Worcester, Mass. Annual Report of Superintendent of Sewers for 1916.

Miscellaneous.

Canada, Department of Mines: Annual Report of Mineral Production of Canada during Calendar Year 1915; Preliminary Report of Mineral Production of Canada during Calendar Year 1916; Report of Building and Ornamental Stones of Canada, Vol. IV, by Wm. A. Parks; Coal Fields and Coal Industry of Eastern Canada, by Francis W. Gray; Value of Peat Fuel for Generation of Steam, by John Blizard.

Institution of Civil Engineers (London). Minutes of Proceedings, Vol. CCII.

National Board of Fire Underwriters: Reports and bulletins on the following cities: Allentown, Pa.; Altoona, Pa.; Baltimore, Md.; Binghamton, N. Y.; Chicago, Ill.; Columbus, Ga.; Detroit, Mich.; Easton, Pa.; Erie, Pa.; Hagerstown, Md.; Hamtramck, Mich.; Hartford, Conn.; Highland Park, Mich.; Lancaster, Pa.; Minneapolis, Minn.; Newcastle, Pa.; New York, N. Y.; Newport, R. I.; Norfolk, Va.; Pawtucket and Central Falls, R. I.; Phoenix, Ariz.; Portland, Ore.; Richmond, Va.; St. Paul, Minn.; Syracuse, N. Y.; Taunton, Mass.; Toledo, Ohio; Washington, D. C.; Waterbury, Conn.; Wilkesbarre, Pa.

Portland Cement Association: Concrete Septic Tanks; Concrete Ships; Concrete Tile for Land Drainage; Protecting Concrete Work Done in Warm Weather; Simple Forms for Concrete; Tennis Every Day on Concrete Courts; Why Build Fireproof?

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.—METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — On July 28, 1917, a contract was awarded to Fred T. Ley & Co., Inc., of Springfield, Mass., for the sum of \$74 477, for the construction of a three-phase, 66 000-volt transmission line, 15.6 miles long, between the Wachusett power station at Clinton and the Sudbury power station at Southborough, Mass.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work in progress: *South Metropolitan System.* — Sections 98-102, Wellesley Extension.

North Metropolitan System. — Section 1, outfall extension at Deer Island.

Alteration Work. — Change in Charles River Sewer in Brighton to accommodate City of Boston surface drain.

METROPOLITAN PARK COMMISSION. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and Quincy is in progress.

Old Colony Parkway. — The work of dredging new channel in Neponset River at new location of Neponset Bridge is in progress.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

SOUTH BOSTON.

(Work being done by department forces.)

B St.,	from West 6th St. to West 7th St.	Macadam.
E St.,	from West 6th St. to West 7th St.	Granite block.

(Work being done by contract.)

W. Broadway,	from Dorchester Ave. to E St.	Asphalt.	(Connell.)
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PROCEEDINGS.

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EAST BOSTON.

(Work being done by department forces.)

Meridian St., from Condor St. to Eutaw St. Macadam.

(Work being done by contract.)

Neptune Rd., from Bennington St. to B., R. B. &
L. R. R. Asphalt. (Donovan.)

CHARLESTOWN.

(Work being done by department forces.)

Water St., near Wapping St. Granite block.

BRIGHTON.

(Work being done by department forces.)

Washington St., from Market St. to Fairbanks St. Macadam.
Beacon St., from Cleveland Circle to Reservoir Rd. Concrete.

(Work being done by contract.)

Turner St., from Washington St. to Faneuil St. Asphalt. (O'Keefe.)
Cummings Rd., from Commonwealth Ave. 855 ft. n'y. Asphalt. (Coyle.)
Glencoe St., from North Beacon St. to Garden St. Asphalt. (O'Neil.)
Waldo Terrace, from Washington St. to Henshaw St. Asphalt. (O'Keefe.)
South St., from Chestnut Hill Ave. to Common-
wealth Ave. Asphalt. (O'Keefe.)
Parkland St., from Winship St. to Academy Hill Rd. Asphalt. (O'Keefe.)

WEST ROXBURY.

(Work being done by department forces.)

Pond St., from May St. to Brookline line. Macadam.
Hyde Park Ave., from Walk Hill St. to Ashland St. Macadam.
Cornell St., from Washington St. to Bellevue Ave. Edgestone.

(Work being done by contract.)

Cornell St., from Orange St. to Colberg Ave. Bituminous macadam. (Reed.)
Richwood St., from Centre St. to Montview St. Asphalt. (Cahill.)
Perham St., from Vermont St. to railroad. Asphalt. (Reed.)
Saville St., from Park St. to Stratford St. Asphalt. (Reed.)
Seymour St., from Brown Ave. to Canterbury St. Artificial walks. (Corcoran.)
Brown Ave., from Poplar St. to Blakemore St. Artificial walks. (Corcoran.)

DORCHESTER.

(Work being done by department forces.)

Adams St., from Dorchester Ave. to Leonard St. Granite block.
Goodale Rd., from Wellington Hill to Blue Hill Ave. Edgestone.
Trull St., from Hancock St. to Bellevue St. Macadam.
Blue Hill Ave., from Talbot Ave. to Mattapan Sq. Macadam.
Linden St., from Dorchester Ave. to Freeport St. Macadam.

(Work being done by contract.)

Southwick St.,	from Neponset Ave. to Freeport St.	Asphalt. (J. Murphy.)
Rowell St.,	from Hancock St. to Cushing Ave.	Bituminous macadam. (J. Murphy.)
Rugby Rd.,	from Randolph St. to Oakland St.	Asphalt. (Cahill.)
Blake St.,	from Randolph Rd. to Hyde Park line.	Asphalt. (Cahill.)
Hill Top St.,	from Granite Ave. to Hallett St.	Bituminous macadam. (J. Murphy.)
Neponset Ave.,	from King St. to Boutwell St.	Artificial walk. (Hayden.)
Dorchester Ave.,	from Freeport St. to Park St.	Artificial walk. (McMorrow.)
Rosemont St.,	from Adams St. to Gustine St.	Artificial walk. (Hayden.)
King St.,	from Neponset Ave. to Adams St.	Artificial walk. (Hayden.)
Dorchester Ave.,	from Peabody Sq. to Washington St.	Granite block. (Connell.)
Dorchester Ave.,	from Savin Hill Ave. to Freeport St.	Granite block. (Hasson.)
Norfolk St.,	from Corbet St. to Blue Hill Ave.	Asphalt. (Coyle.)
Adams St.,	from King Sq. to Ashmont St.	Artificial walks. (Hayden.)

ROXBURY.

(Work being done by department forces.)

Mt. Pleasant Ave.,	from Dudley St. to Vine St.	Macadam.
Warren St.,	from Townsend St. to Grove Hall.	Macadam.
Washington St.,	from Dimock St. to Marcella St.	Macadam.
Waumbec St.,	from Warren St. to Crawford St.	Macadam.
Montebello Rd.,	from Marmion St. to Brookside St.	Macadam.

(Work being done by contract.)

Seaver St.,	from Blue Hill Ave. to Walnut Ave.	Asphalt. (Magner.)
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CITY PROPER.

(Work being done by contract.)

Albany St.,	from Dover St. to Northampton St.	Granite block. (Hasson.)
Haymarket Sq.,		Granite block. (Sheehe.)
Fruit St.,	from Charles St. to Blossom St.	Asphalt. (Magner.)
North Grove St.,	from Cambridge St. to Fruit St.	Asphalt. (Magner.)
Washington St.,	from Haymarket Sq. to Elm St.	Granite block. (Sheehy-Galvin.)
Beacon St.,	from Tremont St. to Park St.	Granite block. (Sheehe.)

New York, New Haven and Hartford Railroad.—CONSTRUCTION DEPARTMENT. — *South Boston Cut Improvement.* — Active construction work of enlarging South Boston cut to Boston Freight Terminal to accommodate four tracks instead of two, and rebuilding of eleven overhead highway bridges so as to span four tracks instead of two, to be started immediately.

Southampton Street Engine Facilities. — Work consisting of new 39-stall engine house, 95-ft. turntable, ash pits, boiler house, office building, and water tank, practically completed with the exception of some minor work. Necessary trackage, etc., progressing.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

HISTORY OF THE BOSTON DRY DOCK.

By JAMES W. ROLLINS,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1917.)

SECTION 12 of Chapter 748, Massachusetts Legislative Acts of 1911, approved July 28, 1911, in part provides:

"The Directors shall report to the next General Court, on or before the 15th day of January, 1912, all necessary plans and estimates of cost for the construction of a dry dock, equipped with modern facilities and appliances, *sufficient in size for the accommodation of any modern ocean steamship.*"

In accord with this resolution of the Legislature, the Directors on January 15, 1912, only five weeks after their appointment, reported as follows regarding the dry dock:

"The short time which has elapsed since the first meeting of the Directors, December 8, 1911, has been insufficient to enable them to organize a technical staff for the preparation of plans and estimate.

"The approximate cost of a concrete or masonry graving dock adequate for any modern steamship, exclusive of land, would probably not exceed \$3 000 000.

"The Directors are of the opinion that a dry dock equipped with modern facilities and appliances, sufficient in size for the accommodation of any modern ocean-going steamship, is desirable and a necessary and essential element in the contemplated development of the port, and recommend that a special appropriation be made authorizing the Directors to build such a dock."

* Of Holbrook, Cabot & Rollins Corporation, 6 Beacon Street, Boston.

On March 4, 1912, the General Court, after having considered the report of the Directors, above quoted, passed an order asking for certain information from the Directors regarding dry docks:

"(c) Whether the building of a dry dock is the first essential step in the development of the Port of Boston?

"*Reply.* — The Directors have already stated in their report to the General Court, under date of January 15, 1912, that a dry dock equipped with modern facilities and appliances sufficient in size for the accommodation of any modern ocean-going steamship is desirable and a necessary and essential element in the contemplated development of the port. As a dry dock of this character requires such a considerable time for construction, we regard it as one of the first essential steps in the development of the Port of Boston.

"(d) Whether, if the building of a dry dock is the first essential of the development of the Port of Boston, it should not be built from the appropriation of \$9 000 000 now at the disposal of said Directors?

"*Reply.* — In view of the fact that the act of the Legislature, Chapter 748 of the Acts of 1911, creating the Port Directors, provided for a special report and recommendation on the subject of a dry dock, and in view of the fact that the Directors have made that report and recommended a special appropriation to build such a dock, the Directors have not considered proceeding with its construction from the \$9 000 000 already appropriated, expecting that the Legislature desires the opportunity to act upon its report."

The General Court, taking the Directors at their word, that they had not had time to properly consider the matter, after having suggested to them that the dry dock should be built out of the \$9 000 000 appropriated, took no further action, and consequently on December 24, 1912, the Directors voted to allot \$3 000 000 for a dry dock, and instructed their engineers to prepare plans and specifications.

The report of the Directors to the General Court in 1912 stated the fact above referred to, and the report of 1913 gave in detail the progress of the engineers' work on the dry dock, presented general plans of it, and gave in full the contract executed with the Cunard, Hamburg-American and International Mercantile Marine Steamship companies, agreeing to build the dock "with all diligence and expedition"; also giving an estimate of the cost of construction of a granite-lined dock as \$2 143 000.

In May, 1914, requests were sent out for proposals for the

construction of the dry dock, and bids were received on June 15; the result being that Holbrook, Cabot & Rollins were the low bidders, and on June 22, 1914, the Directors by a majority vote awarded the contract to them.

Then the trouble began. The vote of the Directors developed two minority votes in opposition to the award to Holbrook, Cabot & Rollins, and these minority directors strenuously opposed the confirmation of the contract to Holbrook, Cabot & Rollins, before the Governor and Council.

Various reasons were presented by the opponents, the chief ones being, that there was not money enough to pay for the dry dock, that the plans and specifications were notoriously incomplete; and on the part of the labor unions, that Holbrook, Cabot & Rollins were "unfair" contractors.

The Council at this time was a Democratic body and did not enthuse over a Republican project of port development in the face of the opposition above referred to; and inasmuch as the Legislature had reconstructed the Directors of the Port, making it a board of three men instead of five, the Council, after weeks of delay and discussion, referred the whole question back to the new board for a report and recommendation, on September 2, 1914.

The new Directors thereupon retained Lieutenant Harris, of the Bureau of Yards and Docks of the Navy Department, an expert on dry-dock construction, and referred the whole matter to him. In December, 1914, Lieutenant Harris made a report in great detail and covering the point brought out by the minority objections as to the completeness of the plans and specifications.

To further help the matter along, some one raised the point as to whether the Directors had any authority under Chapter 748 of the Acts of 1911 for the development of the port of Boston, to build a *dry dock*, anyway. This question was referred to the attorney-general on January 19, 1915, and he reported that, in his opinion, "without further authorization by the Legislature, the Directors of the Port are not warranted in entering contracts for the construction of such a dry dock."

Meanwhile the Directors had made contracts for the con-

struction of bulkheads around the site of the dry dock, and also had made contracts with the steamship companies to build a dry dock, as above referred to.

To settle the question, the Governor, on February 18, 1915, sent a special message to the Legislature, asking them to consider the question as to whether a dry dock should be built, and if so, asking them to ratify and confirm the former acts of the Directors in connection therewith.

Here is where we came in for a new experience, — "politics."

The Legislature, or rather some of its members, considered the question only as to whether a \$2 000 000 contract should be awarded, and acted accordingly, though, at the hearing given by the committee, no opposition was presented on the question as to the necessity of a dry dock in Boston. After weeks of discussion, the Legislature voted, on May 11, 1915, to build the dry dock and confirm the former acts of the Directors in connection therewith.

The Governor, after signing the act, sent a message to the Directors, instructing them to give a hearing, on the matter of the dry dock, and also on the advisability of confirming the contract with Holbrook, Cabot & Rollins, in face of statements made that the prices of materials had dropped and that thousands of dollars could be saved by re-advertising and getting new bids.

This hearing brought out the same group of witnesses — all the public-spirited men in favor of a dry dock and the existing contract, and the labor unions against the latter.

The hearing being favorable, the facts as to prices not being confirmed, and the report of Lieutenant Harris also being favorable, and the investigations of the Board as to financial conditions being satisfactory, the Board by a majority vote made a report to the Governor and Council, on June 22, 1915, recommending that the contract awarded to Holbrook, Cabot & Rollins be confirmed.

About this time, the Governor went away, to California, on a long trip; and on his return and thereafter, in October, 1915, the question of confirmation of the Holbrook, Cabot & Rollins contract came up before the Governor and Council.

Here again the same scenes were reenacted, the minority member objecting, but finally the political curtain was rung down, on October 13, 1915, when the Governor and Council voted to confirm the contract to Holbrook, Cabot & Rollins, sixteen months after the contract had been awarded to them.

Work was begun immediately on the dredging at the site of the dry dock, and was continued all winter, and in the spring of 1916 work was begun on the cofferdam, between the bulkheads already built by the state, the cofferdam being about 500 ft. long. On the line of this cofferdam the elevation of the flats was about 6 ft. below low water, but a channel was dredged from deep water into the dry-dock excavation, 150 ft. wide and 18 ft. deep at low water, to allow the passage of the dredger and scows.

Our contract provided that we should submit to the engineers of the Directors a plan for the cofferdam, and get their approval of the same, before beginning work.

The plan submitted was practically for the same type as that used on the Charles River Basin lock, which cofferdam was most satisfactory and the conditions under which it stood up for two years or more were much more severe than at the site of the Boston dry dock.

This plan was approved by the acting chief engineer, Mr. Robert E. Barrett; by the naval advisory engineer, Mr. DeWitt C. Webb; by the consulting engineers, Messrs. Charles M. Spofford and Guy C. Emerson; and was also approved by the consulting engineers of the contractors, Messrs. Frederic H. Fay and Charles R. Gow.

Some difficulty developed in the dredging of the hardpan overlying the rock, the dredging contractors finally stating, after an extensive series of tests, that the rock was far higher than shown on the contract plans, and thereupon gave up the dredging inside the cofferdam.

The cofferdam was then closed, and work begun on the earth-fill on both sides of and inside the walls.

The question of suitable fill for the cofferdam then came up, as the material which we had expected to get from the dry-dock excavation — sand, gravel and clay — was not forthcoming; so we had to look elsewhere for our filling.

(As a side note it may be said that while a majority of the Directors were favorable to the contractors, the minority member was strongly opposing any action of the Board which could in any way help them.)

On April 27, 1916, we wrote the Directors requesting permission to get suitable material from any source available for the cofferdam fill. No answer was received to this letter. We did get a permit allowing us to use material being dredged by the state in the Mystic River, which seemed suitable for the lower part of the cofferdam fill, but after dumping 10 000 yds., we found it would not stand up, and so abandoned it. We then wrote the Directors asking permission to dredge material in the Reserve Channel, in a portion of that channel which had not been dredged, and which would be an advantage to the state, saving it the cost of dredging at some future time. This request was denied.

We then brought in heavy clay which we were dredging on our contract outside the dry dock, and for a while this material seemed to be fairly satisfactory. Trouble soon developed, as the material being dumped inside the cofferdam would stand up for a short time, but the action of the tide would flatten it out to a very flat slope. We shut the tide gate and tried to make the fill inside free from tidal action; we succeeded in making a fairly good bank, but it soon slumped and flattened out.

We then again asked the Directors for material in the Reserve Channel, but were again denied the privilege, although we offered to pay 5c. a yard for the material. The vote on this was interesting: one member voted to give it to us for nothing, another for 5c. a yard, and the third member voted against giving us anything. So we didn't get any.

We then bought 1 000 tons of gravel and 5 000 tons of stone, putting all this material in one section about 75 ft. long on the south side of the center line of the dry dock.

About this time we closed our gates again, and as the cofferdam seemed to stand up reasonably well, we began pumping, with a 15-in. and a 12-in. direct-connected pump, they having a combined capacity on the first lifts of about 12 000 gals. per minute.

Soon the cofferdam in the weak section began to twist, being 5 ft. out of line at the top, and the sheeting being inclined in both directions, opening at bottom and closing at top, the rods which held it together either breaking or pulling through the timber.

The stone fill was not satisfactory, as we could not pack it solidly against the sheeting; so we again asked the Directors for permission to dredge material in the Reserve Channel, offering to pay 5c a yard for it, and a majority of the Board voted to allow us this privilege. We then put in about 10 000 yds. of good sand and gravel into the rock fill, and apparently solidified the embankment acceptably.

However, something happened, suddenly, as at high tide, at 8.30 P.M. on July 25, a section of the cofferdam collapsed, and the area inside was flooded.

There has been a great deal of discussion about this cofferdam, its design, and its failure; and the writer believes that in justice to all the engineers concerned, a full statement of conditions and facts is desirable.

The contract borings at the site of the cofferdam showed, in all but one boring, a stratum of silt, stiff clay, hardpan to rock, with no porous stratum whatever. Lieutenant Harris had an additional boring made closely adjacent to the questionable one above referred to, and this was a core boring. The sample produced by the drill showed an absolutely hardpan stratum overlying the rock, and not sand and gravel as shown by the contract borings. Lieutenant Harris in his report to the Directors stated, —

Page 6, Appendix B:

"At my request, your office arranged for an interview between Mr. Rollins, of the Holbrook, Cabot & Rollins Corporation, the low bidders, on the work, and myself. This was principally confined to explaining to me, in general details, the methods this company proposed adopting in carrying on the work if it were awarded to them, and especially the type of cofferdam they had estimated on constructing. From this interview I gathered that this company planned to build an enclosing cofferdam across the entrance to form a complete water cut-off if, on further investigations by borings made by them, this was found necessary.

"I was not definitely informed that steel sheet-piling would be used,

driven to rock, but understood from Mr. Rollins that they planned to use this material if further examinations required. When this contract is awarded, the contractor should be required to construct an enclosing cofferdam, across the entrance, of steel sheet-piling driven to rock, unless further examination of the harbor bottom gives different results from those recently obtained. It would be understood, of course, as now required by the form of contract and specifications, that this would not preclude other necessary protective and precautionary measures along the two sides and the head of the Dry Dock as might be found necessary during the progress of the work."

The writer's judgment on this cofferdam was that it was not necessary to drive sheeting to rock, unless there developed a water-bearing stratum overlying the rock. To make sure of the conditions, we made six additional borings on the line of the cofferdam, and in no boring was any porous stratum found.

Having these facts before us, the final plan of the cofferdam, and location, was settled, the cofferdam being moved out from the end of the dry dock 175 ft. and the sheeting was to be driven at least 5 ft. into the stiff clay.

This was the plan approved by the seven engineers above mentioned, not one of whom questioned the stability of the structure.

In a report to our corporation on this matter of underground water, Mr. Charles R. Gow said:

"Since the proposed sheeting will extend through the silt layer, we can eliminate any question as to that material. The substantial blanket of blue clay which underlies the silt is, of itself, to all intents and purposes, absolutely impervious, and therefore if the sheeting is driven 5 ft. into the layer as proposed, I can see no reason to apprehend any percolation through it. In fact, no better material for shutting out water could be desired.

"The only question remaining for consideration is the possible porosity of the sand, gravel and clay stratum overlying the ledge.

"From an examination of the samples of this material and a discussion which I had with the foreman who made the borings, I am satisfied that the material will prove almost equally satisfactory for the purpose of excluding water as will the clay itself.

"With regard to the question of a possible water-bearing seam between this material and the ledge, I have serious doubts if such a general condition could exist, as it has been my observation in the past, that this material is almost invariably cemented to the ledge itself, and while an occasional pocket of coarse material might be found here and there, at scattered intervals, such a condition will be in general unusual.

"I see no reason to believe that the use of the proposed design will lead to any troublesome leakage. On the other hand, I believe it is absolutely improbable that any form of sheeting can be successfully driven through this hard material to the ledge."

Mr. Gow's judgment of subsoil conditions has been absolutely justified by the development of excavation now made (May, 1917).

No leaks of any importance came through the cofferdam, only one, of a few gallons per minute, at high tide; and on the east side two close together from a gravel stratum on top of the rock were developed. The hardpan overlying the rock, at some places 8 ft. in depth, is so hard that a most powerful Marion shovel has difficulty in digging it; and Mr. Gow's statement regarding the impossibility of driving any kind of sheeting through this material has also been proven true, as we tried to drive steel sheeting, for a test well, to rock, with a heavy steam hammer, and were unable to get it through the hardpan.

With the results of all these investigations in mind, backed up by the opinion of all the experts, and the proven stability of a similar dam under more serious conditions, we felt absolutely justified in proceeding with the construction of the cofferdam on the approved plan.

We have omitted one interesting episode in the history of the cofferdam. In February, 1916, certain interests protested to the Governor that the cofferdam we were constructing would endanger the lives of the workmen, who would have to work "hundreds of feet below the water level"; so the matter was referred to the Directors. The correspondence in the case follows:

(COPY.)

BOSTON, February 24, 1916.

Civil Engineer F. R. HARRIS, U.S.N.,
CHIEF OF BUREAU OF YARDS AND DOCKS,
NAVY DEPARTMENT, WASHINGTON, D. C.

My dear Mr. Harris:

In your report dated December 1, 1914, to the Directors of the Port of Boston in the matter of the Commonwealth Dry Dock at South Boston, Mass., you made several references as to the advisability of using steel sheet piling driven to rock in the construction of the cofferdam across the easterly

end of the Dry Dock unless further examination of the harbor bottom should give different results from those previously obtained.

After the approval, on October 13, 1915, of the award of the dry dock contract to Holbrook, Cabot & Rollins Corporation, that firm caused a series of six borings to be taken along the proposed site of the cofferdam. Blueprint copies of sketches showing the results of these borings are appended, marked "A" and "B." These borings were made by Mr. Charles R. Gow (Mem. Am. Soc. and President of the Boston Society of Civil Engineers), and a copy of Mr. Gow's report, dated December 31, 1915, on these borings and on foundation conditions at the site of the cofferdam is appended, marked "C."

During the latter part of December, 1915, the question of cofferdam design was discussed informally with the contractor. On December 23, 1915, the contractor submitted a tentative design with a letter of the same date, a copy of which is enclosed, marked "D."

On December 30, 1915, a further communication on the subject was received from the contractor, a copy of which is attached, marked "E," and on the same date a revised plan of the cofferdam was submitted bearing the approval of Mr. Frederick H. Fay (Mem. Am. Soc.) as consulting engineer.

Copies of the contractor's letter and of the cofferdam plan are attached, marked "F" and "G."

The Directors had been kept informed by their Acting Chief Engineer of the above steps and particularly of the fact that while your report advocated the use of steel sheet piling driven to bed rock, the contractor did not propose to use this material for the reasons set forth in the attached letters.

On January 4, 1916, the Acting Chief Engineer, by the authority of the Directors, submitted the question of the cofferdam design proposed by the contractor to Professor Charles M. Spofford (Mem. Am. Soc. and head of the department of civil engineering at the Mass. Institute of Technology) and to Mr. Guy C. Emerson (Mem. Am. Soc. and consulting engineer to the Finance Commission of the City of Boston) who were some time ago retained by the Port Directors as an advisory board in connection with engineering questions. In submitting this matter to these gentlemen, particular attention was invited to that part of your report in regard to the use of steel sheet piling.

On January 10, 1916, Professor Spofford and Mr. Emerson having examined the plans, specifications and other data submitted to them, recommended the approval of the design. On January 11, 1916, the Acting Chief Engineer, Mr. Barrett, transmitted the report of Professor Spofford and Mr. Emerson to the Directors and recommended that the design submitted be approved "subject to contract requirements." This report was concurred in by Civil Engineer DeWitt C. Webb, U.S.N.

On January 13, 1916, the Directors voted to approve the recommendation of the Acting Chief Engineer, and on January 15, 1916, it was accordingly approved. Construction of the cofferdam was begun on January 27, 1916, and it is now about 10% completed.

Under date of February 9, 1916, the Central Labor Union sent a letter

to His Excellency, the Governor, a copy of which is attached, marked "H." On February 23, 1916, His Excellency, the Governor, and the Executive Council gave a hearing to the representatives of the Central Labor Union in regard to the contents of the above letter. A copy of the brief read by the Chairman of the Port Directors at this meeting is appended, marked "I." After a brief discussion during which statements were made that the construction of the cofferdam without steel sheet piling constituted a source of danger to the dry dock workmen, the subject was referred to the Port Directors for a report.

As the point which is now raised — the safety of workmen — was not specifically covered in your former report, the Directors would appreciate your consideration of and report on the following questions at as early a date as may be convenient.

1. In your opinion does the construction of the cofferdam as approved, subject to contract requirements, constitute a menace or source of danger to the lives of workmen engaged in the construction of the dry dock.

2. Any other points in this connection which you may desire to cover.

Very truly yours,

(Signed) EDWARD F. MCSWEENEY,
Chairman.

(COPY.)

WASHINGTON, D. C., February 28, 1916.

DIRECTORS OF THE PORT OF BOSTON,
40 CENTRAL STREET, BOSTON, MASS.

Gentlemen:

I am in receipt of your Chairman's communication of February 24, 1916, in which in the concluding paragraph you ask:

"In your opinion will the construction of the cofferdam as approved, subject to contract requirements, constitute a menace or source of danger to the lives of workmen engaged in the construction of the Dry Dock?"

While, of course, desirous of answering your question or giving the opinion requested in a direct and brief manner as possible, I find I am unable to do so within the restrictions I understand to be imposed by the question as written, and for other reasons which complicate the issue and which I will give hereinafter.

It is apparent that any probable menace or source of danger to the lives of workmen engaged in the construction of the dry dock that may be occasioned by the cofferdam contemplated, will naturally be dependent upon the security or safety of that cofferdam and I do not understand that your question involves the matter of menace or danger to life or limb of workmen incident to the construction of the cofferdam itself or to the ordinary accidents and casualties which unfortunately are too often inevitable in the carrying

through of work of magnitude such as would be the case in the building of this dry dock. Restricting the menace of danger in the manner I have indicated to cofferdam failure, I would state, as you yourselves undoubtedly know well, cofferdams of the character contemplated to be built by you, do not, as a rule, fail suddenly. There is usually ample warning of impending failure so that your representatives, and undoubtedly the contractors themselves, would, under ordinary circumstances, have an opportunity to safeguard the lives of workmen. I only know of one such sudden failure and this did not result in death or even injury. However, it is not impossible that a cofferdam might fail suddenly and through unforeseen circumstances, cause injury and loss of life. I do not think it necessary or desirable that I should follow out an investigation involving theorizing on probabilities to this extent. You are as well qualified as I am and perhaps better so, to arrive at a conclusion on this scope of the question, so that my answer to your question within the restrictions I consider imposed, is briefly stated as follows:

In my opinion a cofferdam of the character contemplated, if it failed would probably not fail so suddenly as to menace or endanger life but it might so fail if it failed at all.

I have not examined or inquired into the probable safety of the cofferdam proposed by the contractors, Holbrook, Cabot & Rollins Corporation for the following reasons:

(a) The opinion asked for in your communication apparently does not contemplate that I shall do so.

(b) The data furnished to me by you as appendices to this communication is not of such a character as would permit me to express an opinion on the sufficiency of the contemplated cofferdam. Blueprints A and B purport to show the results of borings made by the Holbrook, Cabot & Rollins Corporation. It is not stated that such borings were made under the supervision and subject to the examination of your representatives. There is nothing to show that water pressure tests have been made in each case at various elevations such as were made under my directions in the case of the exploration borings upon which my original opinion was predicated. While you have forwarded to me a copy of a letter written to the Holbrook, Cabot & Rollins Corporation, signed by Mr. Charles R. Gow, Mr. Gow draws certain conclusions which perhaps with his knowledge of local sub-soil conditions in the vicinity of this work, are well warranted and for which deductions he takes the responsibility. But when you ask for my opinions I, of course, would find it inadvisable to express them except where they are based upon certain examinations made by me or by others in accordance with methods which I should have the privilege of choosing and with an opportunity to make such personal examinations as I thought necessary.

(c) The proposed cofferdam design has been submitted by you to a board of consulting engineers, retained by you, consisting of Messrs. Spofford and Emerson, who, after examination of same, have recommended approval of the design, and furthermore have been examined by your Acting Chief Engineer Barrett and by Civil Engineer DeWitt C. Webb, U.S.N., who have

concurrent in the approval of Messrs. Spofford and Emerson. Presumably, Messrs. Spofford and Emerson are still acting in the capacity of consulting engineers for your Board, and it would be manifestly improper and unprofessional for me to in turn pass on a question that they had already acted on without first being requested by them to do so, unless their connection with your Board had already ceased before the date of communication to me of February 24, 1916, which, I understand, is not the case. The same professional restriction applies with respect to Messrs. Barrett and Webb. Or to state the matter more concisely, all of these four gentlemen have had before them my report to you of December 15, 1915, with the precautionary views expressed by me as to the cofferdam construction, and they have in full knowledge of this, with opportunities for personal examination on the site of boring data, direct conference, etc., recommended approval of the cofferdam plan proposed by the contractors, Hollbrook, Cabot & Rollins Corporation and by their consulting engineers, Messrs. Gow and Fay, and I am unwilling and decline to enter into what might be a controversy affecting the action these gentlemen have taken in good faith and in the discharge of their professional duties in passing on the plans submitted to them, unless either these gentlemen join in requesting me to do so or are no longer connected with your Board officially as employees or retained as engineers at the time that you formally ask for my opinion in the matter.

Respectfully,

(Signed) F. R. HARRIS,

As before stated, the cofferdam collapsed on July 25, 1916.

Careful studies of the wreck were made and conferences held with the Directors' engineer, our experts and the men in charge at the time of the failure. Inasmuch as the cofferdam had stood up under greater tides with less filling, it never was satisfactorily explained why the failure came, but the probable cause was the sliding of a great mass of the clay either in the fill or in the natural ground, which released the stone and gravel fill on the inside of the wooden structure, and so allowed that to break.

The writer's first plan was to dredge out the whole clay stratum and drive steel sheeting through the hard pan to the rock, if possible. Further study and thought resulted in the belief that the great mass of rock, gravel and clay which was left in the break at about low-water level, was so secure and solid that it would offer the best kind of a "toe" to hold the new fill; the plan being to build a new piece of cofferdam around the

break, using the same design of a wooden dam, excepting an additional spur pile and heavy X-bracing.

Just at this time the Directors of the Port were abolished and the Commission on Waterways and Public Lands appointed, and it was "suggested" to us by a state official, that we "wait a bit" before going ahead with the repairs to the cofferdam.

The Commission thought it proper and wise to get other experts to report on the cofferdam, and retained Messrs. Ripley and Barnes, of Albany, N. Y., as consulting engineers. These gentlemen came to Boston, visited the Dry Dock, asked a few questions of the engineers of the Commission and of the contractor, one of them at least took his first sail in Boston Harbor, on a power boat, out to the dredge and back, and soon after made a report, a copy of which follows:

BOSTON, MASS., August 23, 1916.

COMMISSION ON WATERWAYS AND PUBLIC LANDS,
STATE HOUSE, BOSTON, MASSACHUSETTS.

Gentlemen: In accordance with your oral instructions we have made a careful inspection of the local conditions at the site of the Boston dry dock, the construction for which is now under contract with the Holbrook, Cabot & Rollins Corporation. Examination was also made of the cores of the borings taken on site of the dry dock. The records of the borings were studied and the reports submitted by the different engineers connected with this work and the correspondence relating to borings and cofferdams have been read. We are now prepared to submit a preliminary report on the reconstruction of the cofferdam, which failed on July 25, 1916.

It was noted that the cofferdam, as built, consisted of two rows of timber sheeting 6" thick, the inner or westerly row being 35 feet long, and the outer row 40 feet long. The sheet piling was driven about five feet into the blue clay. The two rows were eight feet apart and the space between was filled with the blue clay which was excavated from the bed of the bay over the site of the dry dock. Along the westerly face of the timber sheeting an embankment was built of the blue clay material, topped with gravel and large pieces of granite riprap. This bank was about 15 feet wide at elevation 110.0, and its maximum height was at elevation 114.0. Before the construction of the cofferdam the contractor had excavated a channel to a depth of 18 feet at low tide for the passage of his floating plant.

The borings show that the bed of the bay is silt and peat. Underlying the silt is a layer of blue clay five to twenty-five feet thick; then, underneath the blue clay and immediately overlying the rock is a blanket five to twenty feet thick of sand, gravel and stiff clay. The break occurred where the con-

tractor had excavated the channel above mentioned, and some 250 linear feet of the dam was involved in the movement. For about 100 feet both rows of the timber sheeting were broken. The clay and riprap filling placed westerly of the sheeting was washed into the dock pit, being flattened to a slope of about 1 on 5.

At the time of our inspection excavation of this material was being made with an orange peel bucket. It was noted that the rehandling of this material had reduced it to a soft, mushy consistency. At our request the contractor pulled several pieces of the timber sheeting from both the inner and outer rows near the center of the break. Examination was then made of the location and character of the breaks. The contractor also drove a round timber pile 50 feet long about 40 feet into the material near the south end of the break. At this depth the pile failed. The pile was then pulled and the break was found to be about 10 feet from the lower end.

Records show that the tideway gates were closed at noon on Monday, July 10, 1916, and pumping was started on July 12. A movement of the sheeting started with the first high tide after the tide gates were closed and varied from a few inches to nearly two feet in mid-section of the cofferdam. The recovery towards original position at low tide was nearly equal to the high tide movement. This continued for five days, after which no recovery is indicated, but the top of the sheeting tended to progressively move to the west.

It is evident that the embankment placed west of the dam had started to slide and no longer fulfilled its purpose of supporting the sheeting. With the lowering of the water from the dock pit about eight and one-half feet, a head of about 18 feet at high tide was created. This was more than the cofferdam nine feet in width could withstand, and its failure naturally followed.

Mr. Rollins, one of the members of the firm of contractors, informed us that they planned to repair the cofferdam by practically the same construction as originally used, except they would drive a better pile for each of the vertical round piles along the westerly row, and would use sand and gravel for filling the cofferdam and for the embankment alongside.

From our experience with clays similar to the blue clay underlying the silt on the site of this cofferdam, we believe that another break will take place while the dock pit is being unwatered or shortly after the unwatering has been completed, if the cofferdam is repaired as planned by the contractors. We are also of the opinion that the shore ends of the dam now in place are likely to fail, and it would be surprising if they do not, if subjected to extreme conditions which will obtain during the construction of the dock.

The material remaining along the westerly face of the present cofferdam will surely slide into the dock pit when the support of the water is withdrawn. Slides of this material are liable to start at any time, but more particularly when blasting of the rock is being done. It is, therefore, our judgment that the present cofferdam cannot be made adequate, and should be abandoned. An entirely new cofferdam of different design should be built on a location about 150 feet from the present one.

The essential requirements of the new dam should be:

- (a) Stability within itself.
- (b) Pounded in firm, unyielding material.
- (c) Shall cut off, so far as practicable, flow of water in any of the formations overlying the bed of rock.

There are various methods by which these essential features can be accomplished. Among them might be mentioned the pneumatic caisson method; a stone filled timber crib placed in a trench excavated into the gravel formation; steel sheet piling with gravel fill.

We have considered these and other types of cofferdam construction, and, for various reasons, have discarded all but the steel construction.

We, therefore, recommend the steel piling construction, largely of the cellular type, gravel filled, each piece of piling to be driven to refusal with a steam hammer, properly adapted to this class of work.

Owing to the urgency of this preliminary report, details of design have not been fully prepared, but completion of design can be made if desired, so as not to delay progress of the work.

When the location for the cofferdam is determined upon, the elevation of the rock surface and character and depth should be developed by borings.

We have made only a rough estimate of the cost of a steel piling cofferdam, gravel filled, on the last location. We are of the belief that this can be constructed of new steel for less than two hundred thousand (200 000) dollars. We have ascertained that the material can be delivered in Boston as rapidly as it can be used. The time of construction should not extend over a period exceeding ninety days.

We have also ascertained that second hand sheet piling is available for a considerable part of the piling construction. If obtained it will materially lessen the cost of construction.

Respectfully submitted,

(Signed) JOSEPH RIPLEY

M. G. BARNES

Consulting Engineers.

(COPY.)

SEPTEMBER 26, 1916.

COMMISSION ON WATERWAYS AND PUBLIC LANDS,
BOSTON, MASS.

Gentlemen:

Our report dated August 23, 1916, relative to failure and reconstruction of the cofferdam located at east end of the dry dock pit was followed by oral request for making sixteen wash drill borings at indicated places. Your Commission had the borings made and also, in connection therewith, the necessary tests to determine the flow of water into and out of the pipes used for casings.

The kind of material and its permeability will be more fully determined

when the test pit has been excavated to rock. However, the borings and water tests show that the water in several of the pipes fluctuates with the tide with an amplitude of about eight feet and lags behind the tide about one and a half hours. The inflow as determined by pumping ranged from a small amount to as much as twenty-one gallons per minute. This shows the advisability of having the cut-off curtain of the cofferdam extended down to the rock surface.

The borings also disclose the greater depth to and the variable change in dip of rock surface along the location suggested by us for site of a new cofferdam about 150 feet east of the present one. The range in depth of rock is 45 to 66 feet below low tide. The latter depth will make it both expensive and difficult to drive sheet piling to the rock. A change of location is therefore desirable, and rock surface some fifteen feet higher, or about elevation 50.0 can be found just east of and close to the present dam, or within 100 feet west of it. On either of these locations the estimated cost of the cellular type of dam, extended at both ends into the side embankments with a single line of sheet steel piling, will be approximately \$130 000.00, allowing for salvage saving on the steel sheeting. The west location involves moving the dry dock westerly 200 to 400 feet. The elevation of the rock surface permits this to be done if desired.

While examining the test pit yesterday we noted that the contractor was progressing the repairs to the broken part of the cofferdam by placing the six inch timber sheeting.

Under the conditions existing we respectfully advise your Commission to notify the contractor that on account of the failure of the cofferdam as built, the present Commission does not approve of that type of construction, believing that the design is not suited to the material encountered. Also that the Commission is ready to pass on any plans the contractor may submit for a cofferdam but that its approval will be given only to such a plan as the Commission believes to be safe and efficient. Silent acquiescence in the contractor's methods of repairing the cofferdam is at least a negative approval of his type of construction, and in case of failure the Commission may have to share responsibility therefor with the contractor.

A further study just made of the material as disclosed by the recent borings confirms our previous recommendation as to the cellular type of cofferdam being the proper one to build for this place.

In connection with the contract item "Cofferdams," your attention is invited to the bids submitted for this part of the work, the amounts ranging from \$40 000 to \$280 000. As the pumping alone during the three years' construction period will cost more than \$40 000, it is plainly evident that the contractor's bid price for this item is much too low and shows an unbalanced bid.

Respectfully submitted,

(Signed) JOSEPH RIPLEY
M. G. BARNES

Consulting Engineers.

(COPY.)

JOSEPH RIPLEY
CIVIL AND CONSULTING ENGINEER
350 WESTERN AVE.,
ALBANY, N. Y.

DECEMBER 13, 1916.

COMMISSION ON WATERWAYS AND PUBLIC LANDS,
BOSTON, MASS.

Gentlemen:

The examination made by us yesterday of the cofferdam reconstructed by the contractors across the east end of the site of the dry dock disclosed that some of the large pieces of granite riprap at the time of the break had been so deeply imbedded as to rest on the gravel formation and form a toe to the reinforcing embankment. There is some leakage through the superstructure of the dam between half and full tide, the water flowing clear along down the inner slope of the reinforcing embankment at the rate of 100 gallons per minute. The material in the northeast corner is soft and is not supported, the toe being at edge of water in lower pool. Mr. Rollins, the manager member of the firm of contractors, stated to us that he proposed to build a bulkhead enclosing the northeast wing wall. That construction will help prevent the bank from sliding, when the excavation is made 25 feet deeper, for the wing wall. The ridge of rock extending across the dock site and dividing the inclosed area into two parts is very favorable for the contractor as he will have to deal with one part at a time. It is our judgment that the cofferdam from the spillway to the north end should be strengthened by depositing more sand and gravel on the tidal side, and especially it should be well banked up for 100 feet from the north end. The order of prosecuting the work by the contractor will have an important bearing on the safety feature of the work. The best assurance from failure of the cofferdam will obtain if the wing walls and apron are built first and then the side walls westerly to the high ridge of rock. By watching the slopes constantly and taking needed precautionary measures, there should not be any serious slides along the sides of the dock pit. Owing to the unstable conditions at the northeast wing, it is advisable to bulkhead that portion of the work and if possible complete the wall before the spring breakups and heavy rains.

Respectfully,

(Signed) JOSEPH RIPLEY
M. G. BARNES
Consulting Engineers.

(COPY.)

JOSEPH RIPLEY
CIVIL AND CONSULTING ENGINEER
350 WESTERN AVE.,
ALBANY, N. Y.

DEC. 14, 1916.

COMMISSION ON WATERWAYS AND PUBLIC LANDS,
BOSTON, MASS.

Gentlemen:

The cylinder of steel sheet piling having been driven to rock at elevation 56 and the excavation of the test pit completed, we made an examination thereof and also of the physical conditions now existing at the South Boston dry dock on Monday, December 11, 1916. The pumps were started November 1 for unwatering the dock pit. The rate of lowering the water surface was purposely slow so as to give the inclosing banks time to gradually drain out and harden. A ridge of rock and hard compacted material was found extending across the pit a little to the east of center station with its top ranging from elevation 82 to 90. We found that the water surface in the west pool was at elevation 84 and in the east pool at elevation 74. The inflow of water into the dock pit as computed from the gauged flow amounted to about 500 gallons per minute and has not varied greatly from that amount during the six weeks' period of pumping. The water standing in the bore holes previously made has lowered in amounts depending on their distance from the dock pit. The evidence gained from these holes together with the pumping record leads us to the conclusion that the material is not excessively water-bearing. It does show, however, that it is sufficiently water-bearing below elevation 80 to permit the banks to drain out and readily become stable. The water has been drained from the grounds inclosing three sides of the dock pit as is shown by the lowering of the standing water in the bore-hole pipes some seven feet. The water in the pipes still follows the tidal changes, but with a much lessened amplitude, which we interpret to indicate a small quantity of water in the ground, which is generally subjected to quite high pressure. The material excavated from the test pit furnishes definite information as to the kinds and depths of materials encountered. This information is much more conclusive than could have been obtained from the small bore-holes made. The excavation of the test pit furnished very definite information as to variance in materials encountered. After the overlying filling, the silt and soft clay had been removed down to elevation 80, an intrusion of fine sand and gravel was found. Coarse gravel appeared at elevation 75 and largely predominated to elevation 65, then a blanket of hard clay, sand and gravel about nine feet thick overlying the slate rock. We had a half-inch hole drilled through the steel sheeting on south side of pit at elevation 75, and inch holes drilled at elevations 70 and 65. No water came through the upper two holes and only a cupful through the lowest hole. Undoubtedly a cone-shaped portion of surrounding ground with its apex at bottom of the pit had been drained of water by the pumping out of the test pit. If half a dozen

similar test pits had been made in suitable locations quite definite conclusions could be made as to the probable stability of the banks and amount of pumping necessary to keep the pit dry. However, after examining the exposed slopes it may be reasonable to assume that the main part of the banks will average about the same as was found in the test pit, and that the material below elevation 80 will be firm and stable at a slope of 1 on 2 or thereabouts. It is our opinion that the expenditures made for the test pit were fully warranted, for the value of the information obtained therefrom exceeds the cost.

(Signed) JOSEPH RIPLEY

M. G. BARNES

Consulting Engineers.

This report, as will be seen, condemned the whole scheme of our cofferdam; these experts asserting their belief that the balance of it would collapse and recommending the construction of a new cofferdam, of steel sheet piling, of cellular construction; estimating the cost of this as \$200 000.

Regarding self-supported cofferdams, the writer has "no use for them," and it is of interest to read the opinions of other experts on this type of construction, having reference to two of the heaviest cofferdams ever constructed, viz., the cofferdam for the battleship *Maine* and the one for the 46th Street Pier in New York. These opinions are:

THE MAINE COFFERDAM AND ITS LESSONS.

(Engineering News, July 23, 1914.)

"The *Maine* cofferdam was composed of a series of circular cells, each 50 ft. in diameter. Total length about 1 000 ft. Cells were filled with mud. Depth of water 35 ft. with mud bottom about 120 ft. above rock. Piles were 70 ft. long and penetrated about 10 ft. a dense mud or clay stratum. The cylinders proved anything but rigid; they bulged and broke. Large amounts of riprap were dumped inside the dam, and finally heavy braces across the excavation had to be installed. The original estimated cost of the work was \$300 000 and the total expenditure \$785 774.83."

COFFERDAM FOR 46TH ST. PIER, NORTH RIVER, N. Y.

(Engineering Record, July 18, 1914.)

"Extended analyses and computations showed that pockets large enough to possess independent stability due to the width of base and the gravity moment would require very large dimensions and the material available for filling was not suitable or satisfactory. . . . It was believed that a single line

of steel sheeting to serve as a water-tight core for a dam embankment would not have sufficient stability in the soft river bottom before it was reinforced by the embankment, and it was therefore determined to provide pockets large enough to give independent stability during construction, but not large enough to resist the final working pressure, and to reinforce them by the deposition of heavy fills of riprap in the interior of the dam which are calculated to be strong enough to resist the thrust while the pockets filled with soft material exclude the water."

We, as contractors having faith in Boston engineers and our own judgment of conditions at the cofferdam, and having no particular faith in the opinion of engineers who had no knowledge of general Boston Harbor conditions, or of our cofferdam in particular, declined to consider their recommendations, and after waiting several months for some word from the Commission, began work on the repairs, and pushed this work through to completion on November 1, 1916, and on November 2, 1916, we began pumping.

We had no difficulty in pumping the water down to Elevation 80, and in fact we had to shut down the pumps at frequent intervals to allow the water to drain out of the slopes.

From Elevation 80 down to Elevation 70 we were troubled with the soft mud and clay, which kept sliding into our pump well, and which clay and mud we had to remove with a large clamshell bucket, with a cableway; a slow process.

At this date (May, 1917), the excavation at the outside end is down to Elevation 57, and the lower half down approximately to rock. The leakage is remarkably small, a six-inch automatic pump easily controlling the water; not working half the time.

The writer offers an apology to the members of the Boston Society of Civil Engineers for the reports in detail of this cofferdam failure, but offers them in the belief that it is wise to have both sides of a discussion presented, and that in such a way the facts may be more clearly brought out.

DISCUSSION.

MR. CHARLES R. GOW.* — The chief feature of interest from an engineering standpoint, contained in Mr. Rollins' paper, is the behavior of the cofferdam and the probable cause of its failure.

It seems to the writer that there is a plausible explanation of this action, which fully accounts for each stage of the movement noted.

It is a well-known fact that all clay usually encountered in this vicinity is substantially impervious to water *in its natural state*, and, generally speaking, it is recognized as a stable and dependable class of soil. When, however, it is loosened by mechanical means, especially in the presence of water, its many laminations become separated and broken, and it may then absorb large amounts of moisture and become spongy or at times almost semifluid in character. The more such material is rehandled, the greater becomes this fluid tendency. The contained water of such a mass is held almost entirely in mechanical and not chemical combination, and, when an opportunity is afforded, this water will drain out of the mass, although a considerable period will be required in which to obtain complete drainage. Because of the extremely fine nature of the clay particles, they are easily carried in suspension with the water during this draining process.

The material which Mr. Rollins used for the embankment on the inside of his cofferdam was a mixture of clay and gravel, or what in its previous natural state had been a substantially impervious clay hardpan. This material was first excavated by a dredge, thus loosening its seams and particles. It was then towed to the dry-dock site and finally rehandled into place behind the cofferdam sheeting, where it was deposited in the water. As a result of these operations, the whole mass became thoroughly saturated. No difficulty was encountered in maintaining in position the clay thus deposited until the filling had progressed to a point somewhat above low tide. This portion then became alternately submerged and partially drained at each rise and

* Charles R. Gow Co., General Contractors, 166 Devonshire Street, Boston, Mass.

fall of the tide, — the tide gates being open at this time to prevent unbalanced pressure on the dam. Whenever the clay was uncovered by the falling tide, water drained from its inclined face, carrying much of the clay with it and causing the top portion of the fill to slide and run down the inclined surface of the embankment. This tendency would account for the difficulty observed in raising the level of the fill much beyond that of the tide. When the tide gates were finally closed and the tidal action of alternately saturating and drying the exposed top portion of the clay mass ceased, there was no further movement from this cause. The placing of a large deposit of heavy riprap on top of the fill just prior to the attempt at unwatering the enclosure undoubtedly produced a tendency to displace the now semifluid clay fill just as a wet mass of concrete is laterally displaced when a large boulder is dropped into it.

When finally the unwatering process was commenced, a progressive drainage of the exposed portion of the fill occurred. The entrained water left in the embankment undoubtedly assumed a very steep slope due to the slow draining character of the material. Meanwhile the great weight of riprap filling, which had been deposited on top of the clay, aided the latter in its tendency to slip along the line of water slope. As a result of these conditions, when the unwatering process had progressed for a depth of several feet, this mass constituting the top portion of the fill slid forward into the enclosure, leaving the sheet pile core section unsecured against the outside tidal pressure and resulted in its subsequent collapse.

The fact that the damaged section of cofferdam was reconstructed in accordance with the original design except that gravel filling was substituted for the clay and gravel embankment first used, and that the rebuilt dam is successfully fulfilling its intended purpose now that the enclosure is entirely unwatered, indicates in the writer's opinion that the character of the filling was entirely responsible for the failure.

The small quantity of leakage which now occurs in this completely unwatered enclosure calls to mind the predictions freely made during the early stages of the work that unless a core of steel sheet piling driven to ledge was adopted by the

contractors, serious leakage and probable undermining of the cofferdam structure was likely to result. This criticism of the type of cofferdam adopted by Mr. Rollins was concurred in by several prominent authorities. Such a steel pile core would have added very materially to the cost of the work, and in the opinion of many practical engineers and contractors of this vicinity would not have been successfully driven because of the unfavorable nature of the materials to be penetrated.

The assumed need of such a water cut-off was based upon the presence of sand and gravel strata in the underlying clay bed as disclosed by a few of the test borings.

In some instances these strata were undoubtedly isolated pockets having no direct connection with the tide water. Other deposits encountered may have had such a connection, but if so it is evident that they would tend to resist the free passage of tide water through their void spaces, due in part to the inevitable large loss of head occasioned by internal friction and still more to the silting action so well illustrated by the behavior of slow sand filtration beds in the purification of water supplies.

MR. ROLLINS. — Some of the consulting engineers from the West predicted that the whole structure was going to slip on its foundation when finally exposed to its full pressure. I should like to ask Mr. Gow's opinion as to this possibility.

MR. GOW. — Generally speaking, our Boston clay does not slide in the sense referred to. When exposed to the air it often "air slakes" and disintegrates at the exposed face, and if left a sufficient length of time it will in this manner finally assume a natural slope of between 45 and 60 degrees. If, however, a sufficient slope is given to the initial excavation, this action will cause no movement.

Our clays have a distinct horizontal stratification which is opposed to lateral sliding and which to a considerable degree prevents lateral upheaval such as commonly occurs in the clays of the Middle West.

The facts seem to be that the full test of this structure and its foundation has now been applied for several months without indication of weakness, and if failure was to be expected in any respect it must have occurred before this time. The longer it

now stands, the more remote becomes the possibility of any unfavorable development.

MR. FRANK W. HODGDON.* — This work has been delayed and mixed up with many things besides engineering. In the first place, the design of the dock was started when the commission was actively engaged in work on Pier 5, which took about all of my time. Therefore, at the request of the first Commission, who started work, the Secretary of the Navy assigned Mr. DeWitt C. Webb, civil engineer, United States Navy, to come here to advise in relation to the work and render what assistance he could. Mr. Webb has practically had the direct control of the design. He has helped the Commission and myself and Mr. Barrett — who had charge of the work while I was away — very materially. He was inspector on the dry dock at Philadelphia when it was being constructed, so that he was familiar with that class of work. After the work was finally let by the Commission to Messrs. Holbrook, Cabot & Rollins, it ran along, with nothing being done, as Mr. Rollins told you. I was taken sick and had to leave, being away from the office practically a year, actually for four months, and during the remainder of the time did very little. Mr. Barrett had charge of the work during that time, the beginning of the work and the troubles with the cofferdam occurring while he was in charge. Of course he had the assistance of Mr. Spofford and Mr. Emerson as consulting engineers, although they were not consulted more than twice during the whole time. Mr. Rollins handled the work with his usual energy, and if he had had the proper materials to back up the dam I do not think we should have had any trouble with it. The greatest trouble was due to the dredging of the channel through the location on which the cofferdam was afterwards built, making the height of the dam some ten feet or more greater than was originally planned. If the contractor had had the opportunity to fill that trench (it was about 100 ft. wide on the bottom) with gravel, it would have been all right, but by putting in the soft clay from the harbor dredging, a great mistake was made. If the clay could have been placed in the

* Engineer, Massachusetts Commission of Waterways and Public Lands; formerly Chief Engineer of Directors of the Port of Boston.

condition in which it was dredged it might possibly have stood up, but after being rehandled it became like porridge and unsuitable. I have seen some of the same material after being rehandled and dumped out of cars flow off on a slope of 1 to 25, when they were trying to make it spread as far as it would by dumping. It would average that slope month after month.

Mr. Rollins spoke about the breaking of the sheeting, evidently from the internal pressure of the material filling between the walls of the cofferdam. After the break he took up a number of the planks and found them all broken almost midway of the length. The planks ran about 35 ft. in length, and it was just about 17 or 18 ft. from the upper end that they were broken. He took great care in pulling them up in order to be sure a fresh break was not made. When driving, the walls of sheet piling were held together at about high-water level by a pair of rods at each main pile and another pair of rods at each main pile at about a foot above low water. From low water down 18 or 20 ft. the planks were unsupported. At that depth they entered the stiff blue clay. When the dam gave way the washers on the rods either broke and allowed the rods to pull through the wood or they split the timber. I think the timber gave way in a great many cases. Against the great pressure from the filling between the lines of sheet piling the soft material on the outside offered practically no support. It was like pushing the planking through water. The principal lesson to be learned from the cofferdam failure was that the failure was due to its having no support from outside to resist the interior pressure, owing to the flowing character of the material forming the supporting embankment.

The original design was for a straight dock, as shown on the plan, but when Admiral Harris came he discussed the advisability of adding an intermediate sill. In the original design the filling culverts went through the main walls with the drainage culverts under the floor, but in making the change it was found more economical to have the drainage culverts act as filling culverts in order to control the water better, and it required changes in those culverts in order to conduct the water to the pumps from either section of the dock or from both sections

when the whole dock was in use. The present design calls for only one caisson with which either the interior section or the whole dock can be used, but if later business is found to warrant, by simply building another caisson the interior section can be used for a vessel docked for a long period and the outer for a vessel docked for a short period. The second sill will be of concrete, exactly like the outer sill, and will be faced with granite. One reason for using granite facing for the whole dock is that this is a granite country and we wanted to advertise the granite. The granite will increase the cost about \$180 000. The original design called for the coping and the face and backs of the altars to be of granite, in two courses, one for the top of the altar and one for the back. We had another design which called for facing everything above the low-water level with granite, leaving the concrete face below, but it was finally decided to adopt the proposition to face the whole of the side walls with granite. The floor of the dock will be simply a smooth, granolithic surface. The sill will be of granite throughout. In designing the caisson, we departed to a slight extent from the usual practice in having the caisson built with a wood bearing without any rubber gasket.

One very interesting fact developed in making the investigations. The consulting engineers wanted a certain number of borings made, and we started all the plant we could get to do it, Mr. Rollins kindly using some of his well drills so that we now have six or eight 6-in. pipes driven down practically to the rock, some at the upper and some at the lower end of the dock site. We have been observing, from time to time, the rise and fall of the water in those wells. When they were first driven the water would rise and fall in them with the tide, keeping almost at the same level as the tide in the harbor but a little behind it and of course with not quite as great a range, although within a foot or two of that of the tide. But as the dock began to be pumped out we still got the fluctuation with the tide but with very much less range, and the actual elevation is going down all the time. We haven't finished our observations yet, but at every observation we have taken the level is lower; but there is still a fluctuation with each tide. The consulting engineers at first thought that this indicated a free connection with the

tide outside, and that there would be a very large flow of water into the dock. They appreciated the fact that the wells were driven near the excavation for the dock, and the water might come directly from there. When the dock was closed and the water pumped down to the level of low water, we still got the fluctuation but at a lower level, and it has continued to lower as the water has gone down. The bottom of the wells is at rock, which is generally 40 or 50 ft. below low water. There are six or eight wells, all right around the dock site. The nearest one to the water is possibly 6 or 8 ft. back from the bulkhead in the solid fill and perhaps 40 ft. outside the cofferdam. The level in that is going down, too.

MR. BARRETT. — I should like to ask who proposed driving the steel caisson well, as well as the small 6-in. wells you refer to.

MR. HODGDON. — What the consulting engineers wanted, in the first place, was to determine the location of the rock. This observation of the water was a secondary consideration. They wanted to determine the possibility of there being a big leakage into the excavation, but the wells were principally driven to determine the location of the rock.

MR. BARRETT. — Has the location of the rock at these points anything to do with the cofferdam?

MR. HODGDON. — At some of them, yes. The consulting engineers had a line of borings made on the location which they had determined upon for the cofferdam, to show the location of the rock.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848**PAPERS AND DISCUSSIONS**

This Society is not responsible for any statement made or opinion expressed in its publications

THE DISCHARGE INTEGRATOR.

By C. H. PIERCE.*

THE general use of water-stage recorders in obtaining stream-flow data has necessitated a large amount of office work for the accurate interpretation and computation of the records. As the discharge of a river is in general an increasing curvilinear function of the stage, it is evident that the average gage height for a day during which there is considerable variation in stage does not correctly indicate the average discharge for the day, and when that gage height is applied to the rating table it gives a discharge that is too small. Numerous comparisons of results obtained from computations by different methods have been made by engineers of the Water Resources Branch of the United States Geological Survey, and certain standards were adopted, with the idea of eliminating errors due to incorrect methods. For many stations it was found necessary to compute the discharge for parts of a day, the average for intervals of one, two, four or six hours being used to determine the twenty-four-hour average; occasionally the discharge hydrograph was plotted and the daily average determined by planimeter measurement. These methods of computation, though giving highly accurate results, were laborious and expensive, and effort was made to devise a mechanical instrument that would give a summation of

* District Engineer, Water Resources Branch, United States Geological Survey, Custom House Building, Boston, Mass.

values obtained from a continuous application of the rating curve to the gage-height record throughout the twenty-four-hour period.

Several engineers of the Survey have worked on this problem, and in 1915 Mr. E. S. Fuller, at that time assistant engineer, devised an instrument termed the "discharge integrator," which operates much as a planimeter operates, and contains as an essential element the rating curve of the station. Four of these instruments have been built for the use of the Geological Survey by Mr. C. H. Au, mechanical engineer, who deserves

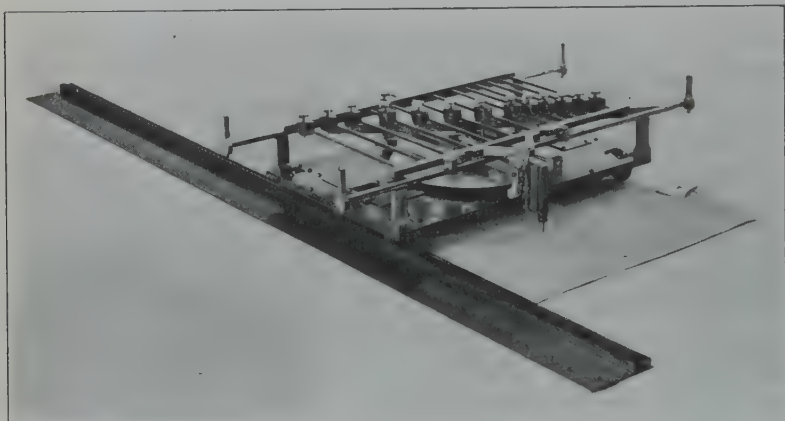


FIG. 1. DISCHARGE INTEGRATOR.

credit for working out many of the details and mechanical features. The discharge integrator in position for use is shown in Fig. 1.

The essential working parts are the rack and pinion, the transmission gears, the driving wheel, the main disk, which is rotated by the driving wheel; the recording wheel, which in turn is rotated by the disk; and the flexible curve, by means of which the recording wheel is placed at distances from the center of the disk representing the discharge at gage heights indicated by the successive positions of the pointer in its movement along the gage-height graph. The parts are so arranged that mean

daily discharge is indicated by the number of revolutions of the recording wheel when the instrument is moved along the rack a distance equal to the length of one day on the record sheet and the pointer caused to follow the gage-height graph.

The theory of the instrument is exceedingly simple, and is based on the fact that for a given distance traveled along the time scale the number of revolutions of the recording wheel is directly proportional to the distance of the recording wheel from the center of the disk, and this distance is controlled by the position of the tracing point, by means of the flexible curve which can be readily adjusted to the rating curve for any gaging station.

In operation, the base plate containing the rack is placed on the record sheet with the beveled edge of the plate parallel to the time axis. The integrator frame is placed in position on the record sheet with the driving pinion engaging the rack on the base plate. The pointer is brought to the gage-height graph at the midnight line and the recording wheel is set to zero. Then the gage-height graph is traced by the pointer for a distance representing twenty-four hours, at the end of which distance the reading on the recording wheel gives the average discharge in cubic feet per second for the twenty-four-hour period. The total length of the base plate is 36 ins., with an effective length of 27 ins. which may be traveled by the integrator for any one position of the base plate. The time required for operation varies with the character of the record and the skill of the operator, but will average from one to two minutes for a day's record. The precision obtained is much higher than that obtainable by other methods, and when ordinary care is used the results obtained by different operators usually agree within a fraction of one per cent.

BOSTON SOCIETY OF CIVIL ENGINEERS

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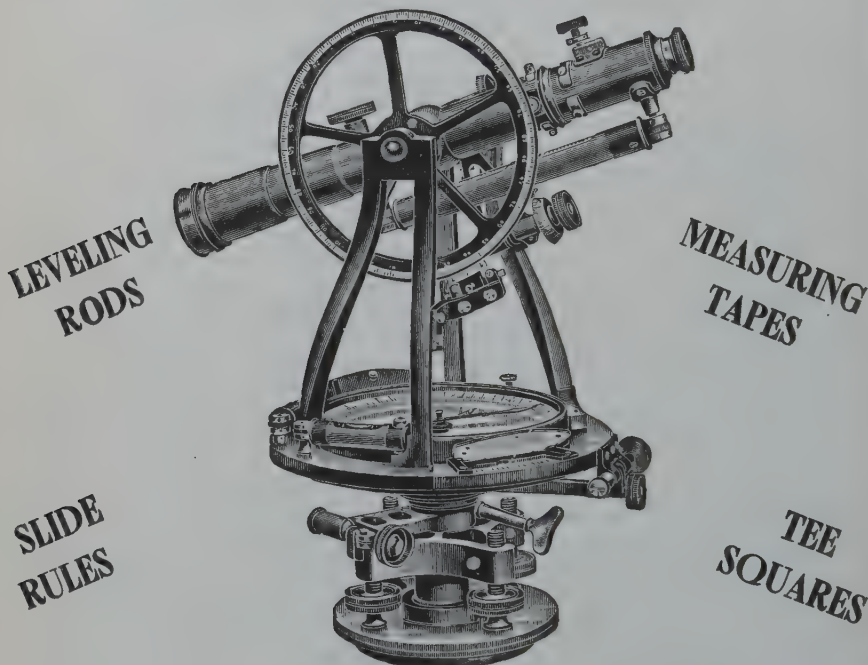
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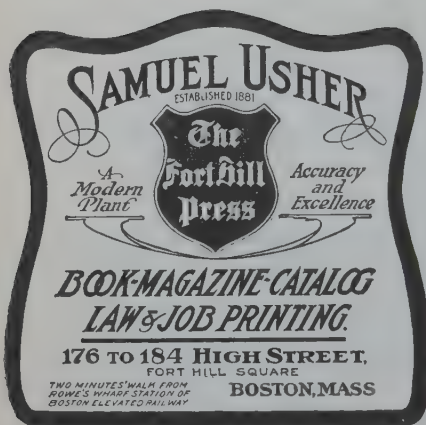
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